Bridging particle and nuclear physics for $0\nu\beta\beta$ with EFTs

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Bridging particle and nuclear physics for neutrinoless double beta decay with EFTs

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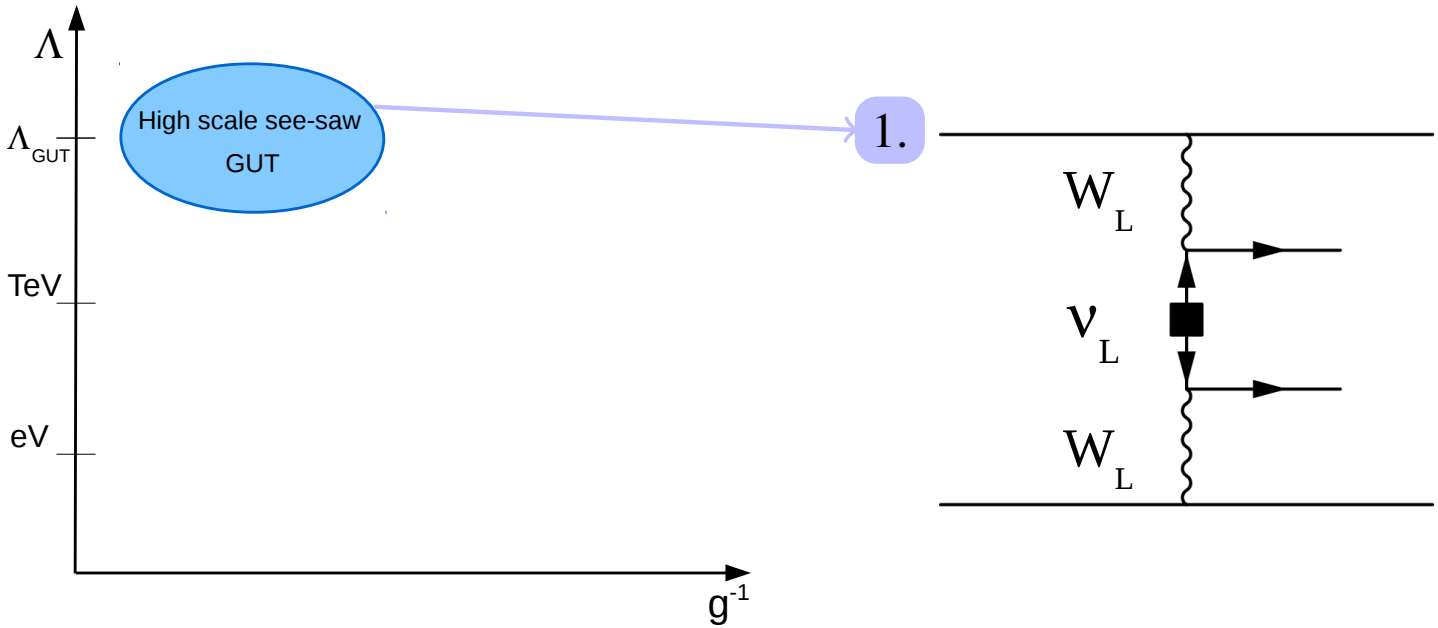
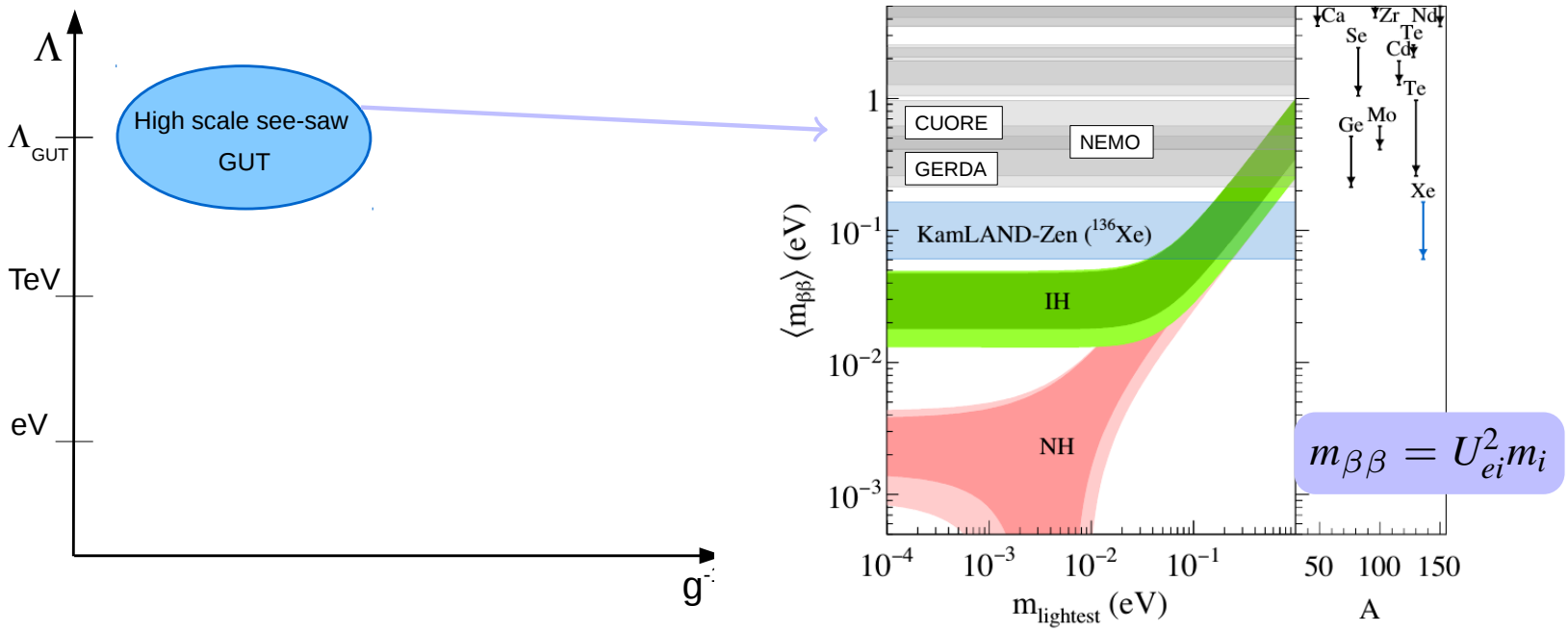
link to LOI



$0\nu\beta\beta$ is the most sensitive probe of lepton number violation (LNV)

1. LNV originates at very high scales
   direct connection between ν oscillations and $0\nu\beta\beta$

Introduction

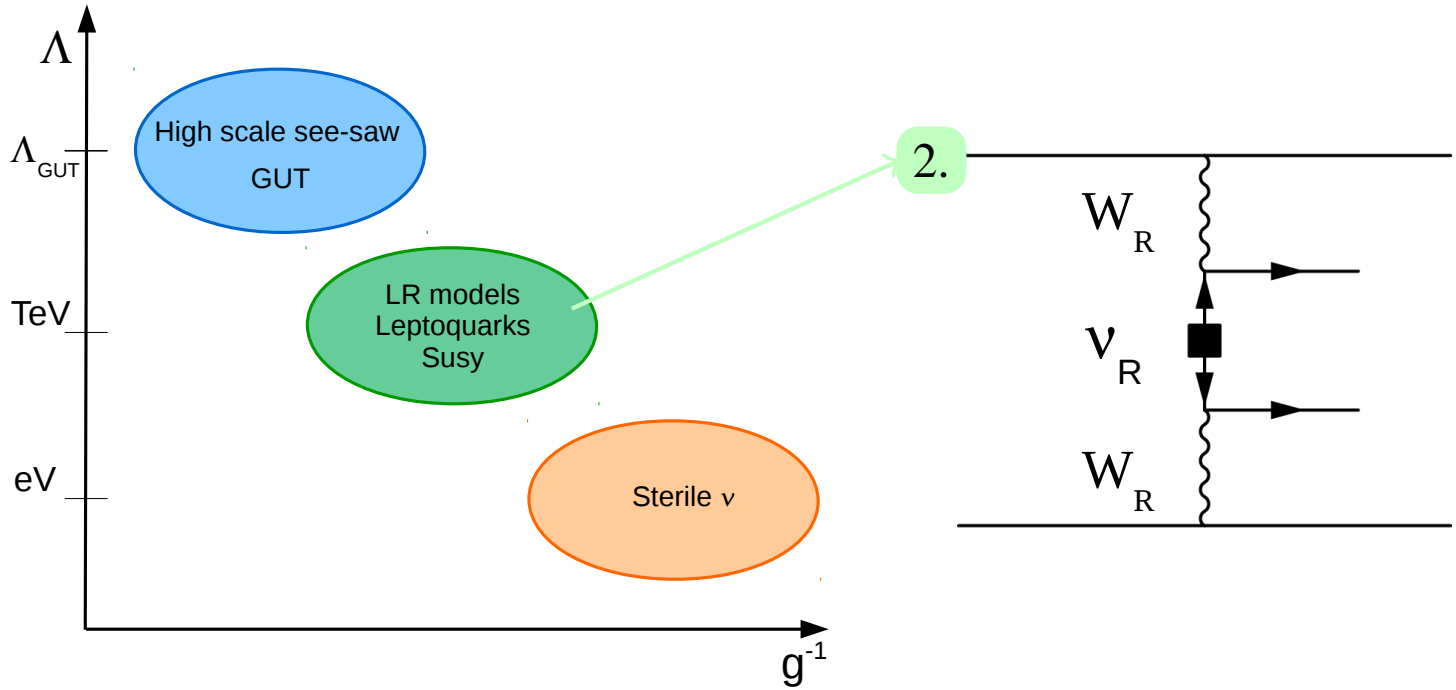


$0\nu\beta\beta$ is the most sensitive probe of lepton number violation (LNV)

1. LNV originates at very high scales

   direct connection between ν oscillations and $0\nu\beta\beta$

   clear interpretative framework and goals



$0\nu\beta\beta$ is the most sensitive probe of lepton number violation (LNV)

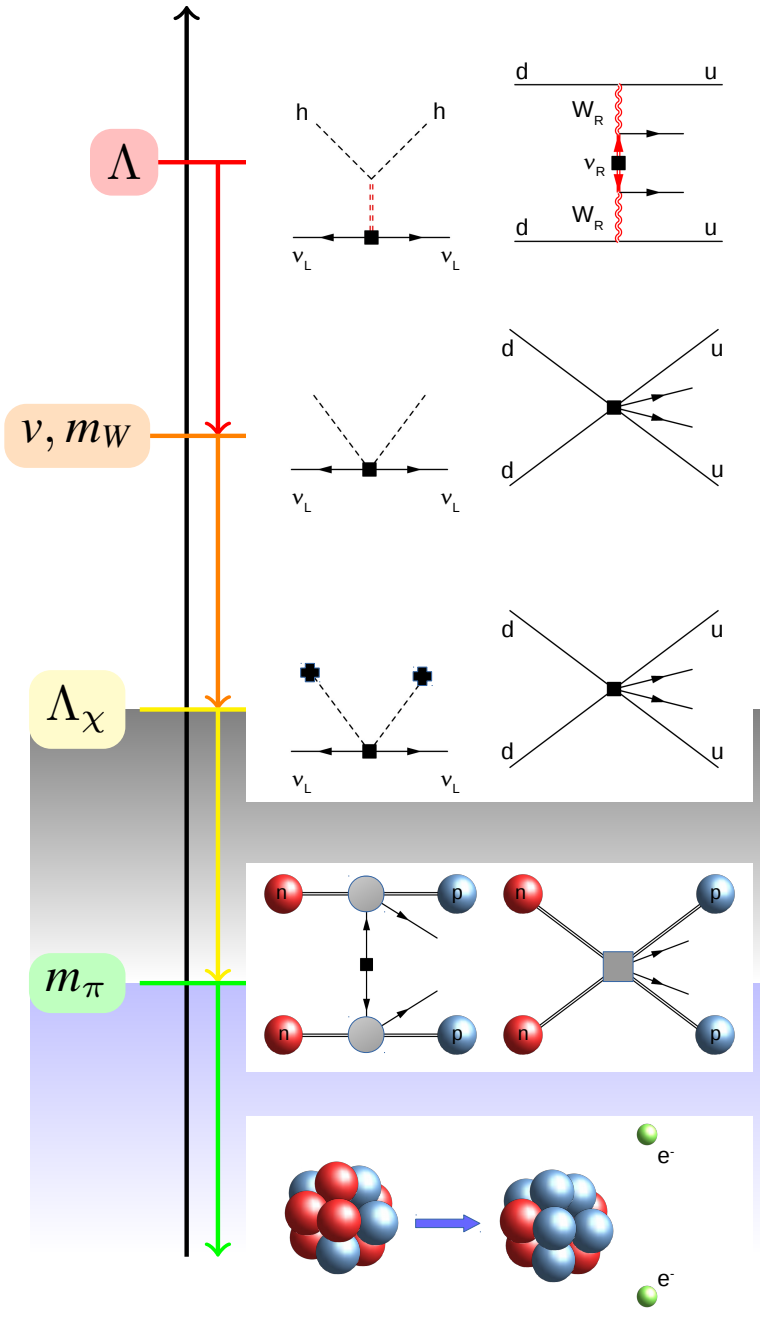
2. LNV at intermediate scales

   $0\nu\beta\beta$ is mediated by new particles, accessible at colliders?

3. very light and weakly coupled new physics

general framework to interpret $0\nu\beta\beta$ exp.?
with controlled uncertainties ?

Effective Field Theories approach to LNV



new physics $\Lambda \gg v$

SMEFT operators

$SU(3)_c \times U(1)_{\text{em}}$ operators

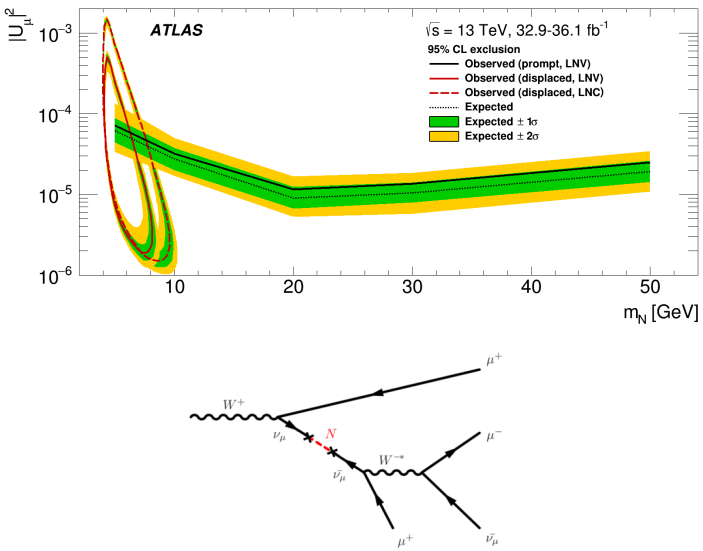
non perturbative QCD

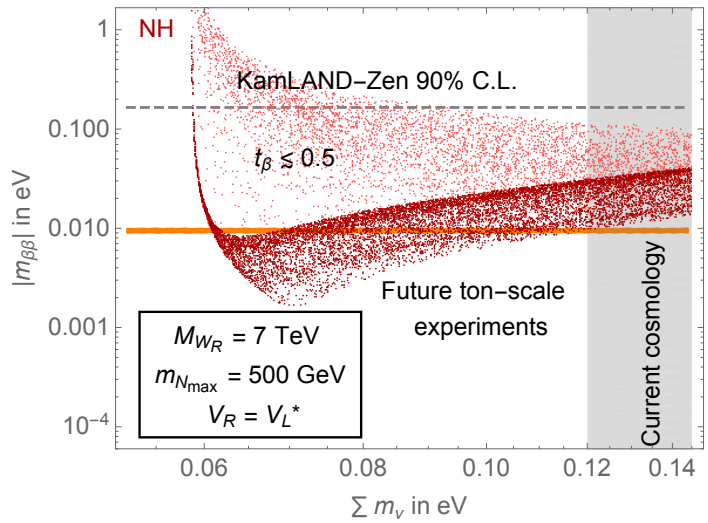
Chiral Effective Theory

strong nuclear interactions

Many body

$0\nu\beta\beta$ and high-energy physics



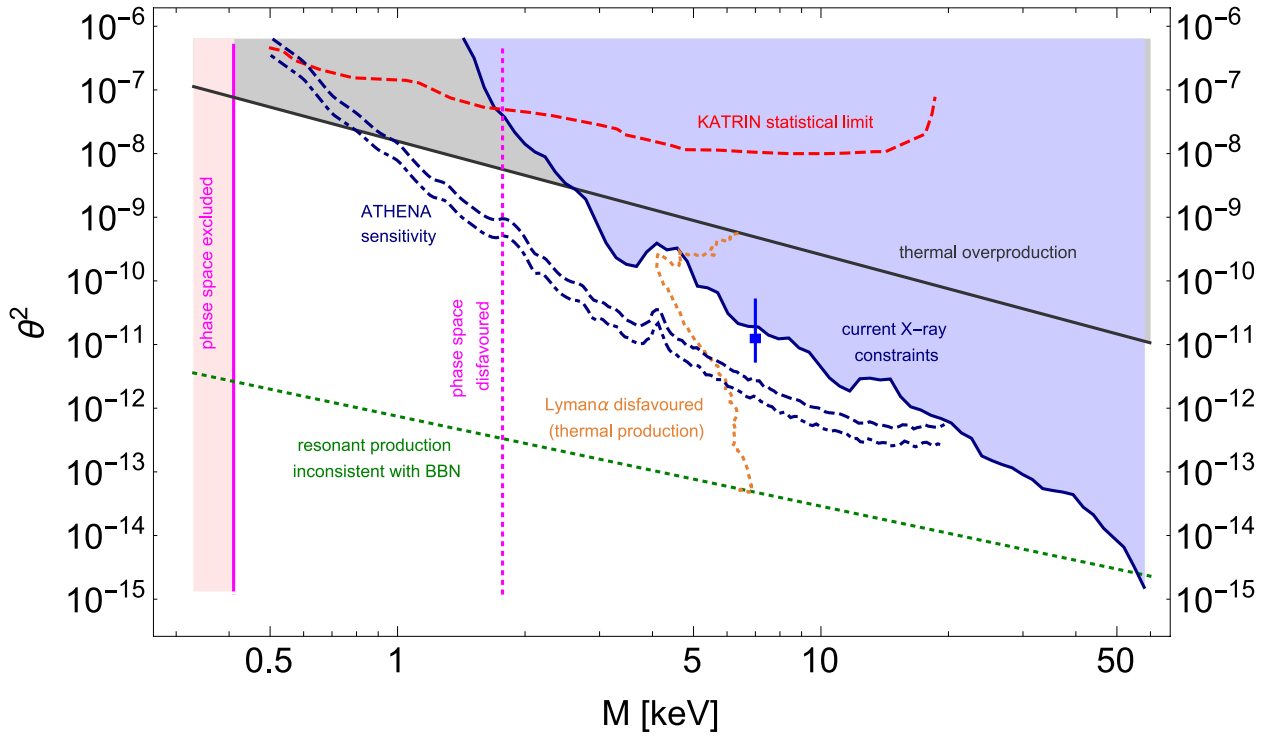


G. Li, M. Ramsey-Musolf, J. C. Vasquez, '20

Q1: What is the connection between $0\nu\beta\beta$ and LNV observables at collider experiments?
ATLAS, CMS, FASER, EIC, ShIP, MATHUSLA, ...

- What is the best strategy to explore this connection?
SMEFT, simplified models, UV complete models?

$0\nu\beta\beta$ and high-energy physics

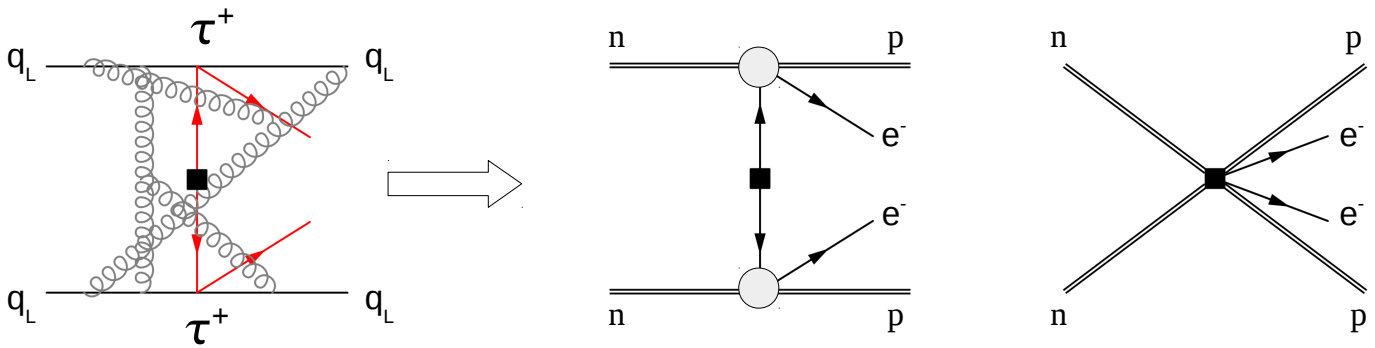


A. Boyarsky, *et al.* '18.

Q2: What are the $0\nu\beta\beta$ constraints on models with ν_R in the KeV-GeV mass range relevant to low-scale leptogenesis scenarios?

- How are such scenarios affected by new ν_R interactions at the TeV scale?

From quark to nucleons



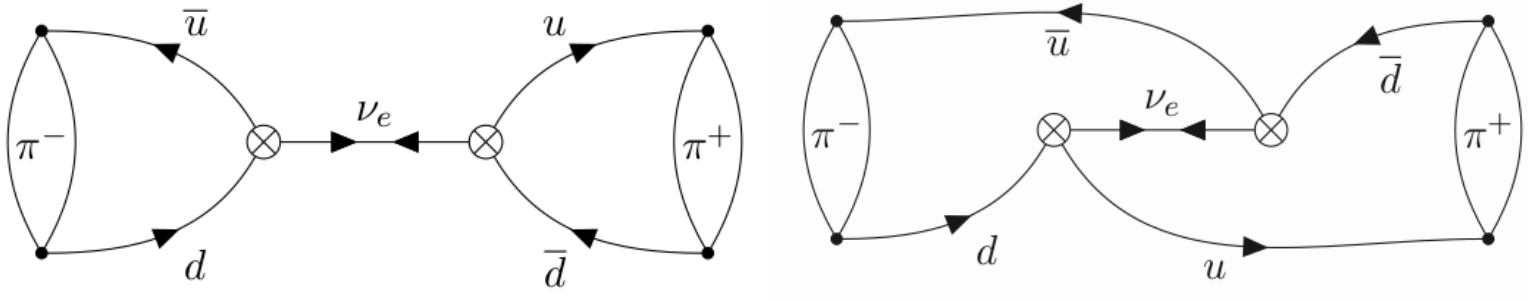
Q3: matching to hadronic EFTs involves non-perturbative parameters (LECs).

- long-range components well determined, for both light ν exchange and TeV scale LNV
- short-range components appear at LO, currently undetermined

  need first principle extraction
- pion matrix elements under control

  X.-Y. Tuo, X. Feng and L.-C. Jin, '19, W. Detmold and D. Murphy, '20
- can we control *NN* matrix elements?

From quark to nucleons



W. Detmold and D. Murphy, '20

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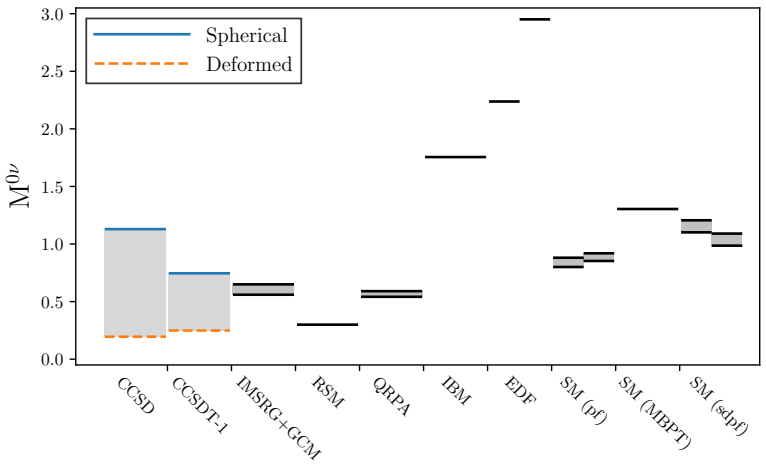
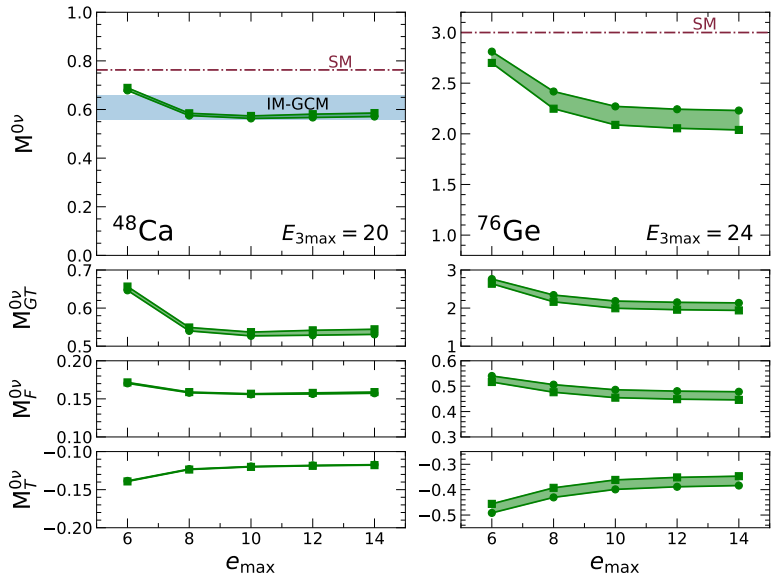
From few-body to many-body



S. J. Novario, P. Gysbers, J. Engel, G. Hagen, '20



A. Belley, C. G. Payne, S. R. Stroberg, T. Miyagi, J. D. Holt, '20

- first *ab initio* calculations in $0\nu\beta\beta$ candidates
- coupled-cluster calculation of $^{48}\mathrm{Ca} \rightarrow {}^{48}\mathrm{Ti}$
- in medium similarity ren. group (IMSRG) for ^{48}Ca, ^{76}Ge and ^{82}Se

Q4: Do many-body correlations preserve the EFT hierarchy of the two-body transition operators?

Conclusion

What will you work on between now and Snowmass, and what is your schedule for developing a contributed paper?

- contributed paper by March/April,
- summarize achievements across the fields of particle physics, lattice QCD, EFTs and many-body methods,
- outline multi-year research plan for the theory of $0\nu\beta\beta$

What common data sets, joint efforts, etc. do you need?

- joint effort between particle physics, lattice and EFTs

What would you like to come out of the Snowmass process?

- support for a theory initiative to coordinate high-energy physics (neutrino mass models, leptogenesis), LNV studies at colliders & lattice QCD and EFT for $0\nu\beta\beta$